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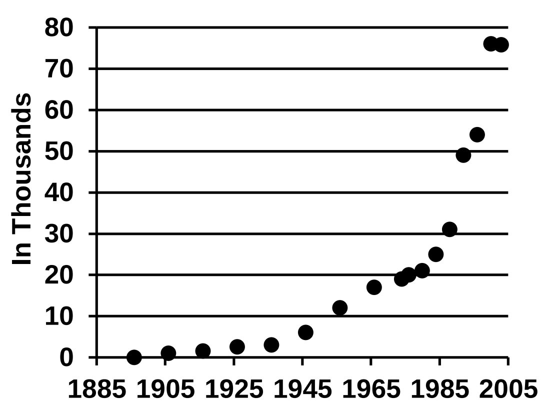
DEER, TICKS, and LYME DISEASE

Deer Management as a Strategy for the Reduction of Lyme Disease

In Connecticut and the northeastern United States, the blacklegged tick, *Ixodes scapularis* (commonly known as the deer tick) is the vector for four disease agents; *Borrelia burgdorferi, Anaplasma phagocytophilum, Babesia microti*, and the deer tick virus (DTV) that cause Lyme disease, human granulocytic anaplasmosis, human babesiosis, and Powassan encephalitis, respectively. There are around 3,000 human cases of Lyme disease reported in Connecticut each year, which likely represents only about 10% of physician-diagnosed cases. Surveys have found that up to a quarter of residents in Lyme disease endemic areas have been diagnosed with the disease and that many residents perceive the disease as a serious or very serious problem. Managing or treating white-tailed deer, *Odocoileus virginianus*, the principal host for adult blacklegged ticks, has been studied as a method for controlling tick abundance since the mid-1980s after Lyme disease was recognized from a cluster of cases in Lyme, Connecticut in 1975. Overabundance of deer has been linked to a number of safety, environmental, and agricultural issues, but Lyme disease and other tick-borne illnesses has been the primary motive for the call to manage or reduce deer populations. This fact sheet will explain the tick-host relationship and why deer reduction has been examined as a method to manage tick abundance and tick-borne diseases.



Historical estimates for white-tailed deer abundance in Connecticut (Data: CT DEP).

Emergence of Lyme Disease . . .

The emergence of Lyme disease can be linked to changing landscape patterns. Through the 18th and 19th centuries, land had been cleared for agriculture and white-tailed deer in many areas were drastically reduced or virtually eliminated due to habitat loss and unregulated hunting. In the northeast from New Jersey and New York to Maine, the deer population is estimated at around 1,918,000 animals [2]. In Connecticut, the number of deer has increased from about 12 in 1896 to over 76,000 today [3] and the actual population may have been as high as 120,000 animals in recent years. Overabundance of deer is associated with problems such as deer/vehicle collisions, agricultural damage, lack of forest regeneration and decline in forest diversity, elimination of native plant species, detrimental impacts on other wildlife (especially birds), residential landscape damage, spread of seeds of invasive plants, and the rising incidence of Lyme disease [1, 4]. With the reestablishment of forested habitat and animal hosts through the latter half of the twentieth century, ticks that survived on islands off the southern New England coast were able to increase and spread.

Today, abundant blacklegged tick populations are found from coastal Maine through the mid-Atlantic and in several north central states, particularly Wisconsin and Minnesota and, recently established in Ohio [5], the tick is now distributed across the entire mid-western to northeastern U.S. This tick is also found throughout the southeastern United States, but human tick bites are much less common and fewer ticks have been found infected with *B. burgdorferi* due to differences in the tick life cycle and available hosts. The major human biting tick in the southeastern United States is the lone star tick, *Amblyomma americanum*, the adults of which also feed primarily on white-tailed deer, or the American dog tick, *Dermacentor variabilis*.

In summary, the rising incidence of Lyme disease has been attributed, in part, to:

- Increased abundance and geographical distribution of the tick
- Overabundant deer population
- Increased recognition of the disease
- Establishment of more residences in wooded areas
- Increased potential for contact with ticks

Figure 1. White-tailed deer at the Bluff Point Coastal Reserve (Groton, CT) in 1994 prior to a deer reduction program initiated in 1996 that reduced the deer population from 220 to 20 deer per square mile [1]. Photograph courtesy Skip Weisenburger.

The Tick Host Connection . . .

Ticks feed on blood and require an animal host to survive and reproduce. The blacklegged tick has four stages; egg, larva, nymph, and adult (male and female). This tick feeds on a wide variety of mammals and birds, although female ticks feed only on medium to large animal hosts. The larvae, nymphs, and adults feed only once and slowly; requiring 3-5 days to ingest the

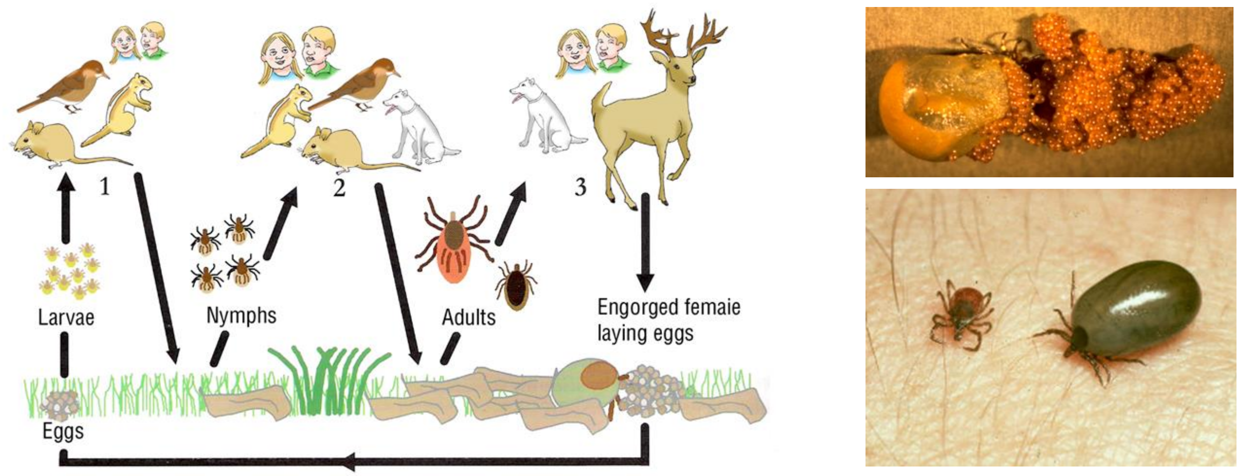


Figure 2. Three-host tick life cycle for *Ixodes scapularis*. Female *I. scapularis* laying eggs (upper right) and an unengorged and engorged female I. scapularis (lower right).

blood, depending on the stage of the tick. Larval *I. scapularis* are almost never infected with *B. burgdorferi*. Larvae and nymphs typically become infected with Lyme disease bacteria when feeding on infected white-footed mice (*Peromyscus leucopus*), chipmunks (*Tamias striatus*), shrews (*Sorax* spp.), or certain species of birds [6-8]. The white-footed mouse is the principal source (reservoir) of *B. burgdorferi*, *B. microti*, and *A. phagocytophilum* [6, 8, 9]. While white-tailed deer are not reservoirs for Lyme disease and do not infect ticks with *B. burgdorferi*, these animals are the principal host for the adult ticks and overall tick abundance has been closely linked to the abundance of these animals [10-12]. Deer may have at least 10 to 50 female ticks attaching and dropping off each day through the fall and spring when adult ticks are active [13]. Each female tick lays around 2,000 eggs and then dies.

While adult *I. scapularis* also will feed on other animal hosts ranging from dogs and cats to opossums (*Didelphis virginiana*), raccoons (*Procyon lotor*), foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), and skunks (*Mephitis mephitis*), they do not feed on rodents and birds. These other larger animals each contribute only a small or modest fraction of the total engorged female ticks to the environment and 50-94% of all engorged female ticks are estimated to come from feeding on deer [14, 15]. It is questionable that *I. scapularis* can be maintained in significant numbers just from feeding on these medium-sized alternate animal hosts. Male *Ixodes* ticks do not require a blood meal and primarily seek female ticks on the animals to mate. Therefore, broadly speaking, deer are responsible for the reproductive success of the tick and mice and other reservoir hosts for the prevalence of infection with tick-borne disease agents. However, larval and nymphal ticks also feed on deer and are important hosts for the immature stages as well. Deer are a dilution host as immature *I. scapularis* feeding on deer will not acquire *B. burgdorferi*. However, this is probably compensated by the number of ticks deer produce and disperse through the environment. White-tailed deer are the reservoir for *Ehrlichia chaffeensis*, the causal agent for human monocyctotrophic ehrlichiosis or HME, which is transmitted by the lone star tick.

Deer Management Strategies . . .

Deer management options include birth control, trap and relocate, fencing and feeding deterrents, deer resistant plants, regulated hunting, controlled hunts, and sharpshooting [1]. There have been three basic approaches explored in relation to managing deer for tick control and Lyme disease. These are deer exclusion, the treatment of deer with acaricides (i.e., insecticides) to kill ticks on the deer, and deer reduction. All these approaches have been shown to significantly impact tick abundance to varying degree and, therefore, the risk of Lyme disease.

Deer Exclusion: Deer fencing can be an effective method of excluding or restricting deer from specific areas. This approach is generally limited to relatively smaller areas or around homes because of installation and maintenance costs, depending on the type and length of fence. In Connecticut, the use of a high tensile electric deer fence at two properties of 8 and 15 acres reduced nymphal and adult *I. scapularis* numbers by 85 and 74%, respectively [16]. No larval ticks were recovered farther than 70 yards inside the exclosures. Similarly, blacklegged tick numbers rapidly declined inside a fenced tract in New York with 84% fewer nymphs inside the fenced area [17].

Treatment of Deer: The topical application of acaricides to both fenced and free-ranging populations of white-tailed deer has been shown to decrease the abundance the lone star tick and the blacklegged tick [18-21]. A “4-poster” feeding device consists of a bin to hold corn and 4 rollers to apply a pesticide (Y-Tex 4-poster Tickicide, 10% permethrin) to kill ticks on deer when they feed. Licensed by the American Lyme Disease Foundation (www.aldf.com), use of the 4-poster device is not approved in all states and permits from state wildlife authorities will generally be required. In Connecticut, the Department of Energy and Environmental Protection regulates the application of chemicals to wildlife [22] (C.G.S. 26-70). Costs for the 4-poster include the devices, corn, rollers, tickicide, signs, applicator gun, and personnel to apply the pesticide and maintain the feeders. In a five state multi-year project of treated neighborhoods or areas, blacklegged ticks were reduced by roughly 60-70% over 5 years of use (~one 4-poster per 120 ac) and further evaluation of the study in Connecticut found a significant impact on the incidence of Lyme disease [23]. Use of the 4-poster at the 600 acre fenced Goddard Space Flight Center in Maryland resulted in a 96-97% reduction in nymphal blacklegged ticks [19]. Additional trials with the 4-poster for the control of the blacklegged tick are being conducted in Connecticut, New York, and Massachusetts.

Deer Reduction: Some communities have explored the reduction of white-tailed deer through regulated traditional hunting, controlled hunts, or sharpshooters to reduce problems associated with deer overabundance, particularly related to Lyme disease. The two major questions have

been how far deer densities must be lowered to reduce tick exposure and human disease and can these levels be realistically achieved? A third element is the community acceptance of lethal deer management strategies [24, 25]. The incremental removal, reduction or elimination of deer has clearly been shown to substantially reduce tick abundance in a number of studies conducted on islands or other geographically isolated areas. Observational studies and computer models suggest that a reduction of deer densities to less than twenty deer per square mile may significantly reduce tick bite risk, while lower levels (~8 deer/mi^2) would interrupt the enzootic cycle of Lyme disease and transmission of *B. burgdorferi* to wildlife and humans. Fewer ticks have been reported at deer densities less than 18 animals/mi^2 in one study [10].

Because of issues related to locations where most deer reduction studies have been conducted and limited human case reports, data on the impact of deer reduction on human disease are more limited. However, reductions in human tick-associated disease with the lowering of deer densities have been reported [26].

- The reduction of deer on Great Island (a peninsula on Cape Cod, MA) by 97% from an estimated 32 deer to 1 animal from 1982 to 1984 (52 deer in all) resulted in ~80 and ~55% average reductions in larvae and nymphs on mice in the 3 years following the intervention. Continued maintenance of a density > 6 deer/mi^2 has reduced tick-borne disease incidence from 16% of a community of 220 people to only 3 cases since 1986 [27-29].
- In the coastal community of Ipswich, MA, removal of deer over a 7-year deer period from 160 deer/mi^2 to 27 deer/mi^2 (~83%) reduced the average number of larval and nymphal *I. scapularis* on mice by 50 and 41%, respectively [30].
- In Connecticut, deer were reduced from > 200/mi^2 to ≤ 30/mi^2 (~84%) at the Bluff Point Coastal Preserve and a geographically isolated tract in Bridgeport (see figure below) producing a substantial (> 90%) decline in tick abundance from 9-12 nymphal *I. scapularis* per 100 m^2 to ~1.0/100 m^2 [31].

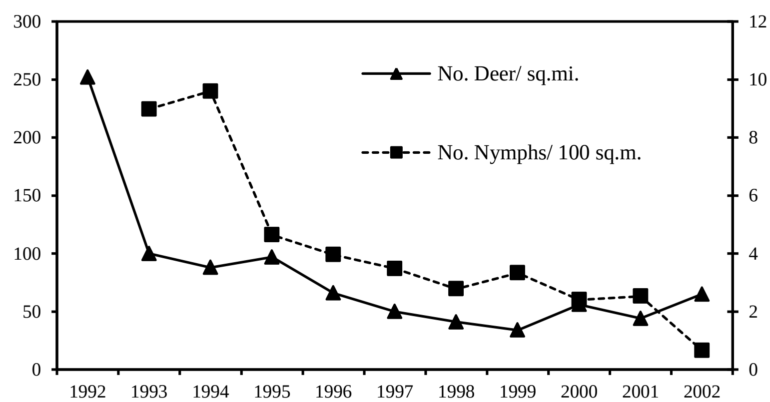


Figure 3. Declining densities of nymphal blacklegged ticks in Bridgeport, CT with the reduction in the density of white-tailed deer from > 200/mi^2 to < 30/mi^2, 1992-2002.

- In Mumford Cove, a residential community in Groton, Connecticut, the deer population was reduced 92% from ~100/mi^2 to ~12/mi^2 through controlled hunts and the number of Lyme disease cases was found to have dropped from 30 to less than 5 within three years. [24, 26].

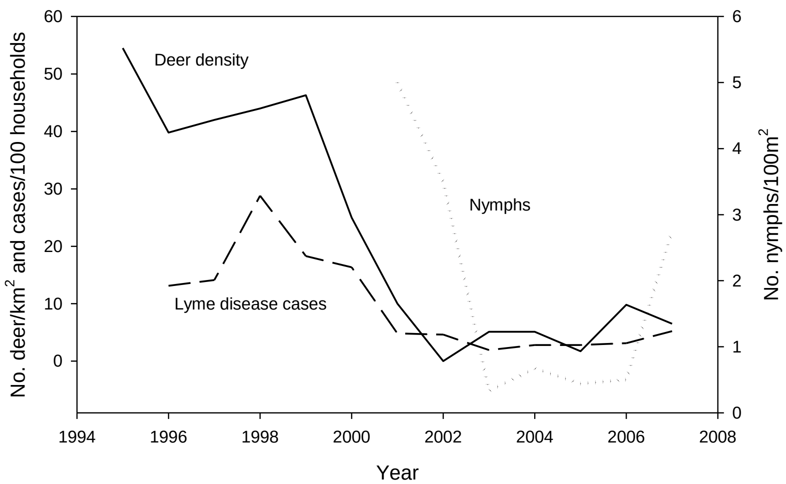


Figure 4. Reduction in deer density, number of Lyme disease cases and number of nymphal blacklegged ticks in Mumford Cove, Connecticut, 1995-2007.

- Deer were completely eliminated from Monhegan Island, Maine over a 28-month period resulting in the steady disappearance of *I. scapularis* from the island [32].
- Computer simulations with a program called LYMESIM suggest that a 70% reduction in deer density and maintenance level of 19 deer per square mile (7.5/km^2) would achieve ~40% reduction in infected nymphs within 4 years. The virtual elimination of deer would result in a 99% reduction in infected nymphs [33]. The LYMESIM model was also used to assess several interventions to prevent Lyme disease under several scenarios for implementation in a hypothetical community of 2,500 homes and included three deer targeted strategies: acaricide to deer, removal of deer, and fencing out deer [34]. Fencing and removal of 80% of the deer was moderately successful in preventing Lyme disease cases as these would result in a transient increase in cases from ticks that were not picked up by deer and a slight increase in the nymphal infection rate. However, in later years, disease incidence decreases with the "dramatic effects of deer removal on tick reproduction" [34].

Deer are not only the major host for the adult stage of *I. scapularis*, many larvae and nymphs feed on them as well [6, 31], although quantitative data are scarce as few deer have been examined during the summer months when the immature stages are active. When deer numbers are initially reduced, more adult host-questing ticks become available to other hosts, including people (providing an "apparent" increase in adult tick abundance), and the infection rate transiently increases as a greater proportion of the larvae and nymphs presumably feed on reservoir competent hosts. Therefore, both apparent tick abundance and the prevalence of *B. burgdorferi* in the ticks will rise before declining in subsequent years. The time that is required for reductions in the questing tick population is due, in part, to the 2 year life cycle of the tick.

The contribution of alternative hosts to the tick's reproductive success is unclear as most are less abundant than deer, have a smaller range, and, in the case of raccoons, ticks may be frequently removed while grooming. Some adult ticks have been recovered from deer-free islands and it is likely a few ticks may still continue to be introduced into an area on migrating birds, even following the complete removal of deer. The issue of host management sometimes gets boiled down to whether it is the deer or the mice, but as already noted, both play an important role in the overall dynamics of the tick-host and host-disease cycles. While the number of spirochete-infected ticks can be related to the abundance of white-footed mice and mouse-targeted interventions have reduced tick abundance and/or infection rates [35, 36], mouse abundance is not necessarily linked to differences in tick abundance in different habitats [37]. There are still fundamental questions in Lyme disease ecology that need to be answered to improve prevention and control strategies [38]. These include identifying host infection rates necessary to maintain transmission of *B. burgdorferi*, understanding the role of habitat differences and forest fragmentation on the risk of exposure to spirochete-infected ticks, and how people are exposed to ticks within or outside the residential setting. And unlike other vector-borne diseases, it has been difficult to assess the impact of tick control interventions on Lyme disease incidence. Certain interventions, such as the application of acaricides, are highly effective, but only reduce risk where they are applied. Deer management strategies, if sufficient, can reduce acarological risk over a larger area than tick control targeted at individual residences and an integrated approach combining the reduction or treatment of deer, treatment of rodent hosts, and the application of acaricides may provide the greatest reduction in the risk for Lyme disease [39, 40].

Table 1. Summary of deer reduction studies and impact on the abundance of *Ixodes scapularis* and the risk of Lyme disease.

Study Site	Deer reduction	Tick reduction	Final nymphal abundance	Impact LD
Great Island, MA	31-51 to 2-7/mi^2	Yes	0.7/mouse	Yes
Crane Beach, Ipswich, MA	44/mi^2 to 11/mi^2 ?	No	2.7 to 1.6/mouse	Unknown
Mohegan Island, ME	100/mi^2 to 0/mi^2	Yes	0/rat; 0.7adults/h	Unknown
Bluff Point, Groton, CT	>200/mi^2 to 27/mi^2	Yes	1.0-4.5/100m^2	NA
Bridgeport, CT	>200/mi^2 to 34/mi^2	Yes	0.7-2.5/100m^2	NA
Mumford Cove, CT	>100/mi^2 to 13/mi^2	Yes	0.04-0.54/100m^2	Yes
Bernard's Township, NJ	118/mi^2 to 63/mi^2	No	1.5-2.6/100m^2	No

Although deer reductions sufficient to impact tick abundance have been successfully carried out on some islands, peninsulas or some other defined geographical tracts (Table 1), it is not clear if a deer population can be reduced sufficiently to achieve a satisfactory level of tick control in more densely populated areas on the mainland. A review of three controlled deer hunting programs (two in New Jersey and one in Pennsylvania) found that several years of traditional hunting along with organized hunting and more liberal regulations could successfully reduce deer densities, but was insufficient to maintain deer numbers below 44 deer/mi^2 [41]. In a New Jersey study, the deer densities were reduced though controlled hunts in a suburban community from an estimated 118 deer/mi^2 to 63 deer/mi^2, which is nowhere near the estimated deer density required to impact tick abundance, and did not result in a decrease in the questing blacklegged tick population [42] (Table 1).

A community that wishes to implement a deer management program, especially in densely populated urban and suburban areas must deal with hunting restrictions, real or perceived safety or liability concerns, and conflicting attitudes on managing wildlife [22, 24]. The failure to achieve lower deer densities desired by communities (e.g., < 26 deer/mi^2) through the use of hunting can be attributed to lack of access to many properties, hunter recreational interests not in line with community goals, lack of appreciation for the number of deer that need to be removed, and failure of hunters to prevent "educating" the deer to hunter presence [41]. Since most land in the northeast is privately held, homeowner views and hunter access are important to successful deer management. Other methods such as sharpshooting, training hunters to more effectively harvest deer in suburban communities, and more liberal regulations may be needed to achieve community deer management goals. Nevertheless, some controlled hunts, as illustrated in the Mumford Cove community, can be successful. In Mumford Cove, a shotgun/archery hunt was used to reduce deer densities by 92% and 82% the first two years, respectively, and a small team of hunters maintained the deer population at low densities during the archery season in subsequent years [26]. Any deer population control program would require an initial reduction phase to lower high densities of deer and a maintenance phase to keep the deer population at the desired targeted level. Deer capacity for reproduction is high and deer herds can potentially double in size in one year. Management would be an ongoing process.

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